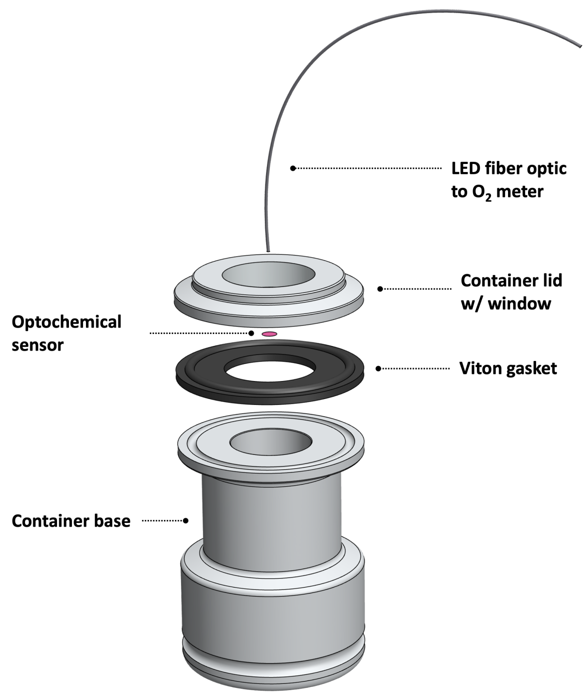
ASSESSING THE OXYGEN PERMEABILITY OF CANDIDATE ASTEROID SAMPLE CONTAINERS WITH OPTOCHEMICAL SENSORS. C. J. Snead[1], S. Martinez III[2], N. Hernandez[2], M. Montoya[2], K. Righter[1], F. M. McCubbin[1]. [1]NASA Johnson Space Center, Houston, TX 77058, USA. (christopher.j.snead@nasa.gov) [2]JETS II, NASA Johnson Space Center, Houston, TX 77058, USA.

Introduction: The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center currently curates 500 mg (10%) of carbonaceous asteroid Ryugu regolith collected by the Japan Aerospace and Exploration Agency's Hayabusa II spacecraft and returned to Earth in 2021 [1]. In September 2023, NASA's OSIRIS-REx spacecraft returned at least 70 grams of regolith collected from the surface of Carbonaceous Asteroid Bennu [2]. These new astromaterials collections are stored and handled in gloveboxes and desiccators that are continuously purged with ultrapure nitrogen in order to minimize contamination and alteration of extraterrestrial samples from terrestrial environments, e.g. reaction with terrestrial oxygen and water. Ito et al. [3] have previously reported on the development of containers to transport samples between facilities in inert, sealed environments; Hayabusa2 samples allocated to investigators by JAXA's Extraterrestrial Sample Curation Center (ESCuC) are shipped in these Facility-to-Facility Transfer Containers (FFTCs). NASA curation has also been investigating sealed containers for storage, transportation, and allocation of Bennu and Ryugu regolith in sealed anoxic environments. In order to assess the ability of candidate sample containers to maintain nitrogen environments, we have utilized optochemical sensors to measure trace oxygen levels within sealed volumes.

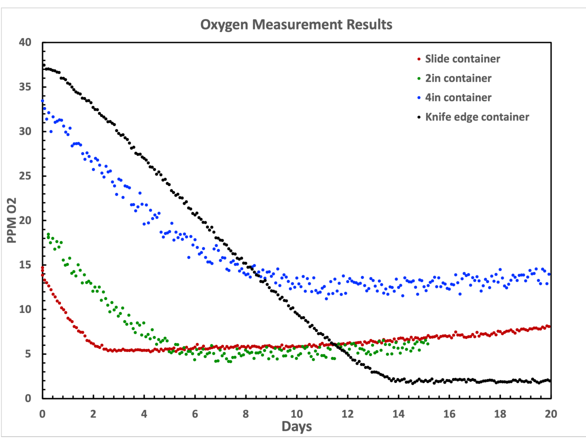
Experimental Setup: The optochemical oxygen sensor system utilized in our measurements is based on dynamic luminescence quenching: LED light of a specific wavelength is transmitted (via optical fiber) to a polymer disk coated with a luminescent dye. The less energetic wavelength of light reemitted by the dye varies in intensity based on the level of oxygen present [4]. This system provides a passive, non-invasive method of measuring an unmodified sample container [4]. We utilized calibrated sensor spots with a range of 0-200 ppm O_2. Each container was placed in a nitrogen-purged glovebox, along with a fiber optic oxygen meter. A spot sensor was fixed either mechanically or with adhesive to an internal transparent container surface (the containers tested needed to incorporate at least one transparent surface, i.e. the containers could not be completely opaque). The end of the oxygen meter's fiber optic attachment was placed normal to the exterior transparent face (opposite the sensor spot), and a measurement was made. The container was then sealed inside the glovebox. We compared the reading for the sealed container with a second control sensor spot that was loose in the glovebox. The sealed container was then removed from the glovebox (as well as the fiber optic O_2 meter). The oxygen meter can perform single interval measurements as well as multiple measurements in time intervals as short as one second. We measured containers in intervals between five minutes to two hours (depending on estimated ingress rates) to assess changes in the internal oxygen environment. By measuring the oxygen concentration of the internal container volume periodically, we were able to determine a rate of oxygen ingress into candidate sample containers.



Results and Discussion: We tested three stainless steel containers that utilized tri-clamp closures and FKM (Viton) gaskets. Each container protected its internal atmosphere from O_2 ingress for 4-5 days. After ~5 days, oxygen ingress results from the diffusion through the sealing membrane (e.g. Viton gasket) and is driven by the partial pressure difference of O_2 between the interior and exterior surface of the gasket, with the flux F equal to:

$$F = K\frac{A(p_1 - p_2)}{d}$$

Where K is the permeation coefficient for Viton, A is the surface area of the membrane, $(p_1 - p_2)$ is the partial pressure difference and d is the width of the gasket [5]. The atmosphere of the testing glovebox typically contained ~20-30 ppm O_2; this trace concentration was reflected in the t=0 measurements for our containers. We observed an initial decrease in the internal oxygen concentrations of the stainless steel containers. While the nature of this decrease is unknown, we hypothesize that trace oxygen in the container reacts with chromium component of the stainless steel composition. The decrease continues until the chromium oxide layer becomes saturated, or until external oxygen diffuses through the Viton gasket. We have also tested a commercially available UHV knife-edge sealed container. The knife-edge container has prevented ingress of exterior O_2 for at least 80 days. This container remains sealed as we continue to periodically monitor the internal O_2 concentration.



Optochemical sensor technology provides a useful, low-cost method for monitoring environments beyond candidate sample containers. For instance, the spot sensors can be temporarily mounted in gloveboxes and desiccators that lack integrated oxygen sensors. These sensors can also be used to empirically determine the diffusion coefficients for various polymers; for instance, it would be useful to have a direct comparison of O_2 diffusion through Viton gaskets and through PTFE gaskets.

References: [1] Watanabe S. et al. 2017. Space Sciences Reviews, 208, p. 3-16. [2] Lauretta D. S. et al. 2017. Space Sciences Reviews, 212, p. 925-984. [3] Ito M. et al. 2020. Earth, Planets and Space. 72:133. [4] Demas, J. et al. 1999. Analytical Chemistry, 71(23), p. 793A-800A. [5] Sturm, P., et al. 2004. Journal of Geophysical Research: Atmospheres, 109 (D4).